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ABSTRACT

This paper reports on a theoretical and empirical study into curriculum innovation in secondary education in the Netherlands focusing on mathematics, physics, chemistry, and biology. Curriculum specialists, subject specialists, researchers, policy makers, and teachers were interviewed for the study. Results indicate that mathematics had the most successful innovations. However, even for mathematics where many innovations were realized at the formal level, it was concluded that little is known about what actually happens in classes. In general, the following factors underlying success in curriculum innovation were found to hold across academic subjects: strongly held and detailed views on the teaching of the subject, an emphasis on developmental research or formative inquiries, the creation of support for the innovation in the relevant educational communities, the legitimization of the innovation through new examination structures, the positioning of key-persons in key-positions in educational institutions, detailed and tested curriculum materials as examples for innovations, the involvement of educational publishers, the existence of centers for curriculum research and development, the stimulating role of charismatic persons or centers, and constant attention to networking among teachers and curriculum developers. Contains 19 references. (JRH)

# Success Factors In Curriculum Innovation: The Case of Mathematics, Physics, Chemistry and Biology In Secondary Education In The Netherlands

by

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## Abstract

*This study is a theoretical and empirical study into curriculum innovation in secondary education in the Netherlands. The study focuses on the subjects of mathematics, physics, chemistry and biology, and covers the last three to four decades of curriculum innovation. The impetus for this study was an expressed supposition by the Dutch Ministry of Education to the effect that curriculum innovation in physics, chemistry and biology might not be as successful as in mathematics. In order to test this supposition and to develop some insight into the reasons for this supposed situation a study was considered desirable. Such a study was designed with the purpose of exploring the state of the innovations in mathematics and science. It was conducted in 1995, with the following research question at its basis: which factors contribute to successful curriculum innovations in secondary education in the academic subjects of mathematics, physics, chemistry and biology?.*

*After a series of searches in ADION an ERIC literature-bases, an interview instrument was developed and in-depth interviews organized. 30 key-persons in each subject (curriculum specialists, subject specialists, researchers, policy makers and teachers) were interviewed. The information gathered from the literature and from the interviews was analyzed in terms of (i) three historical stages in line with trends in the international curriculum literature (ii) a special designed theoretical framework, resulting in a report to the Ministry of Education. Most of the respondents were invited to discuss the conclusions of the report at a conference, organized by the Ministry. After the conference new ideas and suggestions were added to the report.*

*The assumption that innovation in mathematics has been more successful cannot receive a definite answer in the affirmative, although undoubtly mathematics education in the Netherlands has been a kind of Mecca, also for scholars from other countries. All respondents spoke in positive ways about innovation in mathematics. It is the success of mathematics on the ideal and formal level that can be seen as an important factor in the positive image with which innovation in mathematics is viewed; after all the formal level (exams and curriculum materials) is the most visible level. However our findings concerning the success of the innovation in mathematics must be qualified; first, because success in some respects was also found for the other subjects, and, secondly, because the success of the innovation in mathematics itself may be questioned. Mathematics has to prove itself on the operational level and the implementation of the innovation still has not been completed. In this respect mathematics is much like physics, chemistry and biology. From a historical perspective conclusions about the nature of the innovations in mathematics in the Netherlands show a rather unique development of this subject in secondary education. From 1960-1995, a constant set of 'cognitivist and constructivist' ideas, mainly based on European conceptions of learning, has been at the source of the innovations in the Dutch mathematics curriculum, while at the same time ideas such as 'new math' and 'mastery learning' have been ignored. There have been strongly held, detailed views on the teaching of mathematics: 'mathematics as a human activity', 'realistic mathematics education' and 'mathematics for all'. Moreover, factors known from innovation-theoretical research have been helpful in implementing these views especially 'developmental research' and the stimulating role of a charismatic person.*

## Theoretical framework

In order to answer the research question, a theoretical framework was developed based on innovation- and curriculum-theories suggested in the literature. This framework was used for the operationalization of the main concepts contained in the research question: 'curriculum innovation in science education', 'the success of an innovation' and 'the factors involved'. The theoretical framework formed a basis for the definition and specification of these concepts.

*Historical stages in curriculum innovation in mathematics and science*

In the nineteen-fifties and 'sixties mathematics and science education were characterized by an emphasis on the transmission of knowledge and explanations by teachers, with the accent on 'basics': computations, algebraic equations, calculations and drills. As a result of a growing awareness of the problems inherent to this traditional approach several innovations were launched.

In order to describe the nature of the innovations in mathematics and science, three partly overlapping historical stages were delineated. These stages are more or less in line with trends in the international curriculum literature (Walker 1990; Kliebard 1992; Darling-Hammond & Snyder, 1992; Lijnse 1990; De Lange 1987), and may be formulated as follows:

1) *The structure of the discipline as a source of curriculum innovation.*
Curriculum innovations were driven by the idea that scientific concepts, principles, relations and structures are at the heart of innovations in academic subjects (1960-1975).

2) *Curriculum innovation and learning in real-life contexts.*
At this stage curriculum innovators were concerned with the relation between students' daily experiences and school subjects and with issues of individual difference and social justice (1970-1985).

3) *Curriculum innovations from a cognitive perspective.*
Innovations were inspired by studies into 'mediating processes': the processes between the initial state of the learner and his/her learning results. Problem solving, concept-development, conceptual change were important issues in this context (1980-1995).

4) . . . . social - cogn. Vygotsky

*Success of the innovation*

In order to analyze and asses the success of innovations in mathematics and the sciences, certain criteria for success were formulated. As a basis we used Goodlad's distinction (1979) between different manifestations of curriculums. He distinguishes ideal, formal, and operational curriculums, which three manifestations are often used to describe and to analyze educational innovations.

Curriculum manifestations according to Goodlad 1979 ?

| | | |
|---|---|---|
| ideal curriculum ------> | formal curriculum -------> | operational curriculum |



Apple. informal curriculum

In the present study these criteria were used to formulate success at different levels. At the *ideal level* the quantity and the quality of the innovation proposals developed were used as a criterion. At the *formal level* the degree was used to which innovation proposals are accorded a place in curriculums, as manifested in (examples of) exams and especially in particular teaching materials and textbooks. At the *operational level* the criterion was the degree to which innovations find expression in teacher activities. In fact this amounted to a question about the implementation of the innovation.

A fourth level, the attained curriculum, was derived from Van den Akker (1993). The *attained level* concerns the degree to which innovations are reflected in student performance/educational outcomes.

A comparable conceptualization was used in the second IEA-study, which concerned mathematics . At the level of the educational system (the system, the educational region, the school district) there exists a set of intentions with regard to the curriculum. There are goals and traditions. The collection of intended outcomes, together with course outlines, official syllabuses and textbooks, form an intended curriculum. The second level deals with the classroom, the setting in which the content is implemented or translated into reality by the teacher. The classroom is central to the educational process. The third aspect of the curriculum has to do with student attainment.

*Factors involved*

From the literature on innovation theory and research many factors are known which are assumed to influence the success of innovations. In the present study two kinds of factors are important. One group of factors concerns the *development* of new curriculums. The other group of factors is related to the *implementation* of innovations.

*Factors determining curriculum development*

In the present study the term development refers to the processes of design and development. The process of design deals with the specification of the curriculum goals and the curriculum structure. Development refers to the process in which the design is translated into a particular product (Nijhof, Franssen, Hoeben en Wolbert, 1993). The processes of design and development are brought together under the term 'development'.

A framework based on Kimpston and Rogers (1986) was used to categorize factors that determine curriculum development. The categories used in this study are the following: input, context, process and outcomes.

Factors in curriculum development (Kimpston and Rogers, 1986)

| | | | |
|---|---|---|---|
| input | context | process | result |

*The input*

As 'input' Kimpston en Rogers take the characteristics of the participants in the process of development. This can be interpreted as the expertise of the participants, but also, for example, as the composition of the development-team: the presence in the team of teachers, educational psychologists, evalution methodologists etc. The theory or ideology which served as the basis on which the developmental process was started can also be seen as an element of the 'input'; including the extent to which agreement consisted about the theory/ ideology.

*The context*

The context concerns the conditions under which the process of curriculum development takes place. These can be of a material or non-material nature. The following questions are important in this connection. Are there demands from the field for the innovation? Is there external legitimacy for the innovation, such as a new examination program or a large scale innovation that necessitates the innovation with regard to subject matter? Are sufficient resources available? Factors of considerable importance are resources of time and money, as are examples of 'good practice'; for example in other countries, in other subject matters, or in earlier innovations.

*The process*

With regard to the process of development the systematic nature of the development strategy is important: have the necessary stages been passed through as regards concept formulation, construction, formative evaluation and summative evaluation? A second important aspect is cooperation: to what extent and in what ways cooperation between the different experts mentioned above was shaped.

*Outcomes*

Outcomes concern the characteristics of the curriculum product (for example a curriculum or teaching method). In fact the outcomes of the process of development appear as 'input' to the process of implementation.

*Factors determining curriculum implementation*

Our categorization of factors determining curriculum implementation was inspired by Fullan (1982, 1991) and by applications as reported in Dutch educational research (Lagerweij, 1982). We distinguished between socio-political factors, characteristics of the innovation, strategies for implementation and characteristics of the innovating unit. These categories can respectively be interpreted as 'input' (characteristics of the innovation and of the innovating unit), as 'context' (macro-political factors) and as 'the process' of the implementation (applied strategies). However, only the first-mentioned categorization was used. It is important to note in this respect that not only the separate categories, but also their connections have to be taken into account. The four categories are discussed below.

Factors in curriculum implementation

| | | | |
|---|---|---|---|
| macro-political factors | characteristics of the innovation | implementation strategies | characteristics of the innovating unit |

*Macro-political factors*
With regard to macro-political factors it is known that the role of central government can be important. Innovations appear to have greater chances of success if they have been placed in a framework of national policy and are given extra resources (Van den Akker, 1993). The existence of institutions where the process of implementation is initiated and by which it is supported (e.g. the Freudenthal Institute for mathematics and teachers in PLON (a physics curriculum development project of the University of Utrecht) and DBK for physics (a concurrent physics curriculum development project of the University of Amsterdam) also come under this heading.

*Characteristics of the innovation*
Fullan (1982 and 1991) distinguishes four different characteristics: the extent to which the innovations meet the real needs of teachers, the clarity and comprehensibility of the innovation proposal, the difficulty, complexity and extension of the changes with regard to the parties concerned, and the availability of concrete and functional materials.

*Implementation strategies*
Innovation implementation strategies including ways of training, retraining and supporting are dealt with. Cooperation between the different actors and timing are also important aspects.

*Characteristics of the innovating unit*
This denominator is mostly used for the characteristics of the school organization. This level is not taken up in this study. However, the characteristics of individual teachers and of the environments in which they work are clearly relevant. Here characteristics are meant such as capability, willingness to change, resistance and needs, and degree of organization, religious denomination and schooltype.

## Research question

As mentioned earlier, the general research question underlying this study was the following: which factors contribute to successful curriculum innovations in secondary education in the academic subjects of mathematics, physics, chemistry and biology? However, the theoretical framework mentioned above necessitated the following, accompanying research question: which factors in the processes of development and implementation are mentioned in the literature, in particular by key figures, as relevant to successful curriculum innovations in mathematics, physics, chemistry and biology (at the ideal, formal, operational and attained levels)?

## Design

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After a series of searches in ADION an ERIC literature-bases, an interview instrument was developed and in-depth interviews organized. 30 key-persons ~~in each subject~~ (curriculum specialists, subject specialists, researchers, policy makers and teachers) were interviewed. The information gathered from the literature and from the interviews was analyzed in terms of the theoretical framework mentioned above, resulting in a report to the Ministry of Education. Most of the respondents were invited to discuss the conclusions of the report at a conference, organized by the Ministry. After the conference new ideas and suggestions were added to the report (Volman, Vermeulen & Terwel, 1995).

## Results of the study

### I Results: the nature and success of the innovations

With regard to *the nature (content) of the innovations in mathematics and science* the study showed that in each of the subjects (mathematics, physics, chemistry and biology) the historical line was more or less recognizable. However, mathematics was an exception in certain respects. Dutch mathematics curriculum specialists and educators had defended their conception of 'Mathematics as a human activity' against movements such as 'the structure of the discipline approach'. They embraced the idea of 'mathematics in real-life contexts'. It was relatively easy for Dutch mathematics educators to make the connection with recent movements such as 'constructivism' because of their affinity with older European conceptions of learning (Selz, Kohnstamm, Piaget, Wagenschein).

The *success of the innovations* in terms of the degree to which the ideal curriculum is realized in the formal and operational curriculum differs for each subject. We will consequently describe the nature (content) of the innovation together with its success for each subject.

### Mathematics

*1) Structure of the discipline: the New Math movement.*

Already in the nineteen-sixties Dutch teachers of mathematics were aware of the failures of traditional mathematics education, with its emphasis on the transmission of knowledge and the process of explanation by the teacher, and its accent on 'basics': algebraic equations, calculations and drills (c.f. De Miranda, 1966). In the context of the New Math movement 'the structure of the discipline approach' never became very popular in the Netherlands. Perhaps as a consequence of Freudenthal's critique on the New Math movement and his ideas about "mathematics as a human activity", most teachers were reluctant to accept the ideas of the New Math Movement. That is the reason why, at least to some extent, the New Math movement fell on rather barren ground in the Netherlands. The historical stage of the 'Structure of the Discipline' (historical stage 1) was, by and large, skipped in the Netherlands, although there was and still is a curriculum (booklet) which is called New Math (Moderne Wiskunde).

*2) Mathematics in real-life contexts*

For mathematics education it is generally true that the traditional approach of the 'fifties changed straight into stage two and subsequently into stage three. This different place of mathematics is probably due directly to the work of Freudenthal c.s.. Freudenthal defended his concept of 'mathematics as a human activity' and 'mathematics in real-life contexts' against advocates of the 'the structure of the discipline approach' and was strongly opposed to the New Math movement, with its introduction of sets, relations and logic; a position similar to that of Wagenschein in Germany. For Freudenthal New Math was 'mathematics as a system', separate from its context. He highly valued the process of mathematization rather than the results of the process and he and his co-workers consequently embraced the idea of mathematics in real-life contexts (realistic mathematics education) (Terwel, 1990; Terwel, Herfs, Mertens & Perrenet (1994). In the context of the discussion regarding the innovation of the structure (secondary school system) Freudenthal's motto was 'Mathematics for all'. Consequently he proposed a kind of integrated middle school in which students of different abilities worked together in heterogeneous classes and heterogeneous small groups.

*3) Mathematics education from a cognitive, constructivist perspective.*

Freudenthal was inspired by older European conceptions of education and learning, as embodied, for example, in the works of Decroly, Wagenschein, Langeveld, Selz, Kohnstamm and Piaget. Phenomenology, cognitivism and constructivism were important sources for Freudenthal's conception of the mathematics curriculum. However, Freudenthal rarely referred to these sources explicitly. This connection to European conceptions was the main reason why it was comparatively easy, for Freudenthal's coworkers and, more in general, the Dutch mathematics educators, to relate to more recent movements such as the constructivist movement e.g. the work of Paul Cobb (Wood, Cobb & Yackel, 1995). Gravemeijer, one of the current leading researchers in the Freudenthal Institute expressed the relation between realistic mathematics education and constructivism as follows: "The central principle of constructivism is that each person constructs his or her own knowledge, and that direct transfer of knowledge is not possible. This idea of independent construction of knowledge supports the central realistic principle." (Gravemeijer, 1994).

*Success of the innovations in mathematics*

With regard to *the success of the innovations* mathematics appeared to be the most successful. However, even for mathematics, where a lot of innovations were realized at the formal level, little is known about what actually happens in classes. The lack of information about the extent of success at the level of the operational curriculum and the attained curriculum clearly calls for further research. In this respect no differences were found between mathematics and science. As far as *mathematics* is concerned, at the level of the ideal curriculum there is an ideology which has developed historically. However many discussions are conducted internally, there is broad agreement about the basic ideas, as well as the direction of the development of mathematics education. At the level of the formal curriculum innovation in mathematics education has been successful. There are new examination programs and curriculums for the full range of the general streams in secondary education. The principles of Realistic Mathematics Education have to some extent been integrated into all published mathematics methods. With regard to the operational curriculum, mathematics education is at a transitional stage. Many of those involved have noticed a lack of systematic evaluation and support for the way teachers have translated innovation into concrete actions. It is still unknown how lessons are modeled according to the new ideas. At the level of the attained curriculum the conclusion, at least for secondary education, must be that no judgments can be passed.

**Physics.**

*1) Structure of the discipline: the New Physics movement.*
The Dutch Committee for Curriculum Development in Physics was certainly inspired by the 'structure of the discipline' movement. Physics as a school subject was conceived of as providing orientation in modern science. According to this view students need insight into methods, concepts and structures. In addition, skills and strategies are important. Present curriculums and textbooks contain many aspects of this New Physics movement. Typical examples of the structural approach were the well-known physics textbooks 'Physics on a corpuscular basis' and 'The New Physics'. More than was the case for mathematics, the Physics textbooks also followed current learning theories; e.g the strategy of mastery learning.

*2) Physics in real life contexts.*
The second movement also had a high profile in Dutch physics innovation history. The well-known PLON-project is an example of this type of innovation. This project attempted to make physics instruction more meaningful to students by means of a curriculum that can be characterized as 'reality-centered' and 'participation-centered' (Wierstra, 1990). The former characterization refers to the extent to which the physics knowledge is presented explicitly in relation to every-day life. Participation-centered physics education means that the emphasis is on learning activities in which students possess a certain amount of independence, without incessant control by the teacher. In short, 'Physics for all' was one of the inspiring mottoes of the PLON-project. However, this particular innovation was mainly restricted to the general stream of the Dutch educational system. And in this stream the PLON-ideas are familiar but rarely implemented in full.

*3) Physics from a cognitive, constructivist perspective.*
Although the dominant physics curriculum is mainly characterized by the structure of the discipline, many curriculum specialists and researchers in physics education are inspired by constructivist ideas, especially by the work of Driver (1995).

*Success of the innovation in physics*
With regard to the success of the innovation proposals and materials developed at the ideal and formal level in *physics*, the innovation has been successful to some extent because the subject matter in physics education has been changed, and the innovations have been incorporated into textbooks and exams. However, a kind of instruction more directed towards self-activation by pupils has not yet been sufficiently developed. At the level of the operational curriculum the changes have been noticeable, but not considerable. Innovative ideals are generally known by teachers and partly found in the classroom; students work on different subjects than before. However, content-structured-methods yet have to gain the upper hand, and participation-centered

instruction is rarely realized. Differences between schools are substantial in this respect. At the student-level changes were planned in an affective-emotional sense: physics education had to be made more attractive, especially for girls. In general, the main innovative ideas in physics education are still on the level of the ideal and formal curriculum, in spite of the inspiring and innovative PLON-project.

**Chemistry**

*1) Structure of the discipline: chemistry on a corpuscular basis.*
How common the 'structure of the discipline' approach was in chemistry education in the sixties may be illustrated by means of an article written by subject-matter specialist De Miranda (1966). De Miranda was very critical of the general practice at the time, in which many teachers in chemistry taught the structure of the discipline directly. He proposed that chemistry be taught not through simple transmission and explanation by the teacher but by providing students with ways of developing their own chemistry-language, concepts and to discover their own truths.

*2) Chemistry in real-life contexts.*
In De Miranda's critique, his own views on the practice of chemistry education were forerunners in advocating real-life situations in chemistry education. However, the dominant practice was still that of traditional education; that is, the transmission of the structure of the discipline. This approach was far removed from the life of the students and demotivation and inert knowledge were the result.

*3) Chemistry education in a cognitive, constructivist perspective.*
An approach which could be called 'constructivist' ahead of its time was the 'Theory from Experiments' (TFE) curriculum. This is a series of secondary school textbooks which were based on a different concept of chemistry education. The authors apparently adopted the perspective from De Miranda and created a curriculum in the seventies which is still in use today. The curriculum in question is aimed at developing a language on the basis of the student's own experiences and findings from experiments. Working in small groups is the dominant educational pattern in classes in which TFE is used. However, this method was implemented in a very small number of schools. The vast majority of schools work with less innovative, more traditional material.

*Success of the innovation in chemistry*
What can be said about the success of the innovations in chemistry? Most respondents perceived great changes over the last twenty years, however many innovations exist at the level of 'ideals'. The clearest and most successful innovation is the introduction of laboratory work. Since 1972 this is a compulsory part of the school examinations. On the whole the innovation in chemistry education is restricted to the surface. Even on the ideal level the innovation has not yet been sufficiently detailed.

**Biology**

*1) Structure of the discipline*
The innovations in Biology education started relatively late. After the traditional knowledge transmission stage, the dominant ideas, concepts and relations were derived from the structure of the discipline.

*2) Biology in real life contexts*
At the beginning of this innovation movement there was no consensus about the main objectives and ideas. After a rather long and confusing discussion biology education freed itself more or less from the older traditional approach and subsequently also from the more discipline-oriented conception. Biology became more thematic. New topics were selected for the school curriculum including DNA-technology, ecology and immunology. New methods were introduced, for example laboratory assignments, and students became more involved in research.

*3) Biology from a cognitive, constructivist perspective.*
Due to the late start of the innovations this stage is not apparent in biology, except in discussions by curriculum specialists and some teacher educators.

*Success of the innovation in biology*
With regard to the success of the innovation proposals and materials developed at the ideal and formal level in bilogy, the success of the innovation has been limited. Most respondents noticed that the discussion in biology about the ideal curriculum was a difficult and time-consuming process. They expressed some satisfaction about the success of the innovations in biology as far as the formal curriculum (exam and syllabi) is concerned. However the development of curriculum materials and textbooks according to the new ideas is still in its infancy and the implementation of the ideas in clasroom processes is not realized yet.

## II Results: factors determining curriculum development and implementation

With regard to the *factors determining curriculum development and implementation* we concentrate on the question which factors bear the responsibility for differences between subjects. We deal, in turn, with factors that contribute to a successful developmental process, and with factors contributing to successful implementation.

An important factor related to *the input* in the process of development seems to be an unambiguous conception of the direction of the desired innovation. In Mathematics such a consensus was achieved at an early stage. An important role in the development of that common conception was Freudenthal's. He was the charismatic founder and leader of the Freudenthal Institute at Utrecht University. He held coherent views on mathematics education and defended these by fire and sword against critics and would-be intruders. This does not necessarily mean that there were or are no others views; but it does mean that there has been less room for such views.

In physics there are clear differences in views between concurrerent expert centers e.g the PLON-project from Utrecht University and the DBK-project from the University of Amsterdam. In chemistry differences of opinion were found about the relationship between content structures and society at large, and in biology considerable differences of opinion have existed for a long time between followers of more structural and those of more social points of view.

Another important factor with regard to input appears to be the involvement at an early developmental stage of experts of all kinds. Besides curriculum developers, teacher educators, educational psychologists and teachers, publishers, authors of textbooks and representatives of higher education and social sectors related to the subject matter (e.g. chemical industry at chemistry) were thought to be required for the implementation of the innovations. By contrast, analysis shows that when teachers had a substantial say in the various stages of development the innovation often turned out to be successful.

An additional important factor concerning *the context* is the legitimization of the innovation by central government. An explanation for the differences between innovations in mathematics and science can be found in the greater amount of attention the Dutch government paid to mathematics innovations. Mathematics was seen as a subject 'for every one'. Furthermore, the impression gained ground that mathematics-education receives more support from within the discipline than is the case for the other disciplines.

Strongly related to legitimization are the resources available at the start of an innovation. Time and financial resources are required for the development of innovations. In this respect, too, the government plays an important role insofar as it makes the necessary resources available.

In addition, the importance of financing institutions with specific tasks in the area of educational innovation has gradually become more transparent. Almost all the respondents mentioned the concentration of expertise in one institution as an important factor for success in mathematics .

With regard to *the developmental process* a set of three factors was identified as important for success: planning in stages, timing and continuity. Moreover, cooperation between the parties involved appeared to be of great importance. Finally, the advantage of 'developmental research' is mentioned as a factor of crucial importance (Gravemeijer, 1994). Innovative materials have to be based on a proper understanding of learning processes.

With regard to *the outcome* of curriculum development different types of outcomes can be distinguished. These outcomes constitute the different inputs for new developmental cycles (-examination programs, curriculums, sample materials) or for the implementation (textbooks, exams).

From the implementation perspective, one important factor at *the macro-political level* in the Dutch context is the role of centralized examinations in secondary education. Many teachers appear to take an innovation seriously only if it involves a change in examination structures. The Dutch system of centralized examinations can be interpreted as an obstacle on the one hand and, on the other hand, as an enabling factor in that it forces innovations 'from the top down'. Moreover, an 'enabling government' seems to be of importance both for the development and the implementation of innovations.

Factors related to *the nature (content) of the innovation* were found to be related to factors in the process of curriculum development. A balance is needed between the 'intended' innovation and its feasibility for teachers. This balance can be defined as an aspect of the final quality of the outcome. Some examples are the involvement of people 'in the field' as participants in the development of examination programs and experiments, as well as the practice of informing publishers in the early stages of development.

With regard to *applied strategies*, clear variations were found between the subject areas as well as between the various innovations within the subject areas. It seems that the implementations of those innovations that were developed in close connection with professionals in the field had already started. Another important matter with regard to implementation proved to be the introduction of a set of connected measures: new examination structures should be accompanied by the introduction of new teaching materials, by offers of retraining that enable teachers to adopt the innovation model and by new examination questions. Attention should also be given to informing the large groups of teachers who were not concerned with the development of the innovation. Retraining is an important instrument in the creation of expertise and, thus, support for innovations. In addition, publications in professional journals and conferences can contribute to overall success. The networks and structures of the professional associations can be also be helpful in reaching large groups of teachers.

Finally, *characteristics of the field* were found to have an influence on the implementation process. For each subject area it was found that a small group of teachers were the 'pacemakers' and that a small group were implacable opponents. However, the average willingness to accept innovation appears to differ between subject areas. Here again there was the relatively positive adoption in the field of mathematics education. The respondents mention factors such as: the relatively high average age of science teachers as compared to mathematics teachers, the lack of mobility, and the predominance of teachers with 'grade-one teaching qualifications' who were tenacious of more traditional or stuctural approaches. Also noticeable is the greater degree of acceptance towards the tradition of retraining in mathematics compared to physics and chemistry.

## Conclusions and discussion

In general, the following factors underlying success in curriculum innovation were found to hold across academic subjects:

1) Strongly held and detailed views on the teaching of the subject e.g. 'mathematics as a human activity' ,'realistic mathematics education', 'reality centred physics' or physics for all'.
2) An emphasis on developmental research or formative inquiries.
3) The creation of support for the innovation in the relevant educational communities.
4) The legitimization of the innovation through new examination structures.
5) The positioning of key-persons in key-positions in educational institutions.
6) Detailed, elaborated and tested curriculum materials as examples for innovations.
7) The involvement of educational publishers.
8) The existence of centers for curriculum research and development.
9) The stimulating role of a charismatic person or 'high priest' in R & D centers.
10) Constant attention to networking among teachers, curriculum developers and trainers.

In mathematics innovation all these factors were realized, which must constitute an important factor in its success.

The 'neutrally' formulated research question of this study -- i.e., the question of which factors contribute to successful curriculum innovations in secondary education in the academic subjects mathematics, physics, chemistry and biology -- was based on the unproven assumption by the government that innovation in mathematics had been more successful than innovation in science subjects.

On the basis of the present findings the assumption that innovation in mathematics has been more successful cannot receive a definite answer in the affirmative, although undoubtly mathematics education in the Netherlands has been a kind of Mecca, also for scholars from other countries.

Whatever the answer, our findings concerning the success of the innovation in mathematics must be qualified; first, because differences in success were also found for the science subjects, and, secondly, because the success of the innovation in mathematics itself may be questioned. Mathematics has to prove itself on the operational level and the implementation of the innovation still has not been completed. In this respect mathematics is much like science. However, it is the success of mathematics on the formal level that can be seen as an important factor in the positive image with which innovation in mathematics is viewed; after all the formal level is the most visible level.

In spite of these qualifications all respondents spoke in positive ways about innovation in mathematics.

From a historical perspective conclusions about the nature of the innovations in mathematics in the Netherlands show a rather unique development of this subject in secondary education. A constant set of 'cognitivist and constructivist' ideas, from mainly European origine, has been at the source of the innovations in the Dutch mathematics curriculum, while at the same time 'modern' ideas such as 'new math' and 'mastery learning' have been ignored.

In terms of the innovation-theoretical framework there have been strongly held, detailed views on the teaching of mathematics. Moreover, factors known from innovation-theoretical research have been helpful in implementing these views.

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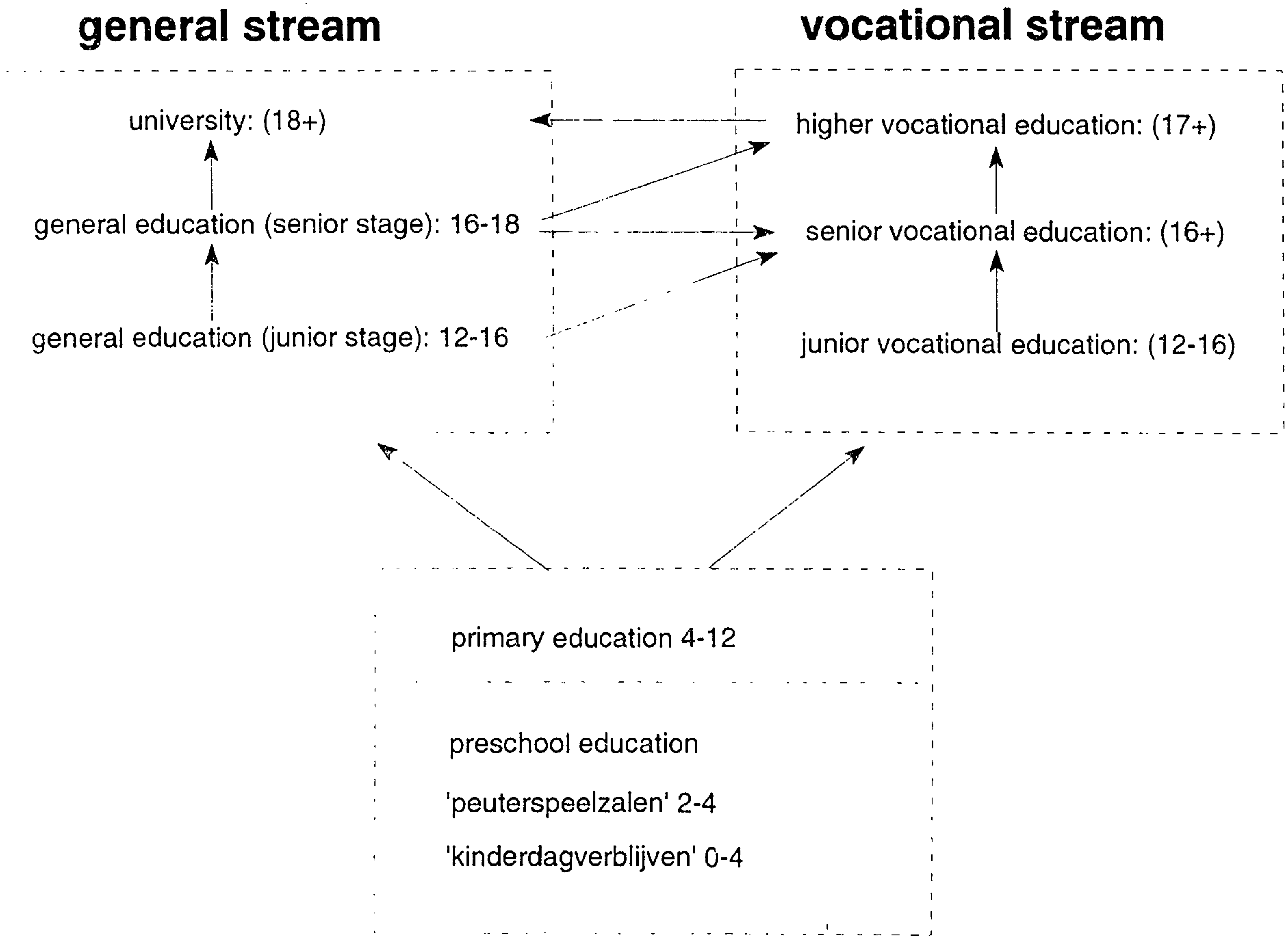
A scheme of the Dutch educational system*




*** This scheme is based on the situation before the introduction of Basisvorming in 1993.**